Composite Materials In Highway Bridge Construction

STUDY PROPOSAL FOR RESEARCH PROJECT 227-1

MARCH 1998

TRANSPORTATION RESEARCH AND DEVELOPMENT BUREAU
NEW YORK STATE DEPARTMENT OF TRANSPORTATION
George E. Pataki, Governor/Joseph H. Boardman, Commissioner

A. Identification

Study Title: COMPOSITE MATERIALS IN HIGHWAY BRIDGE CONSTRUCTION

Agency: Transportation Research and Development Bureau
New York State Department of Transportation
State Campus, Albany, New York 12232-0869

Principal Investigator: Tadeusz C. Alberski
Civil Engineer II

Section Supervisor: Sreenivas Alampalli
Engineering Research Specialist II

B. Problem Statement

Rapid deterioration and consequent costs for maintaining highway structures built with conventional materials warrant consideration of alternative construction materials. Fiber-reinforced plastic (FRP) composite materials, due to their strength and material characteristics, seem to offer great promise in solving many existing roadway infrastructure problems. Although extensive research is underway nationwide in using FRP for bridge-retrofitting applications, progress has been limited in using FRP for new construction. Research in this area seems to have followed a component approach (i.e., focused on such individual components as decks, girders, piles, etc.). A systems approach may be much more productive in advancing FRP use in new bridge construction.

C. Objective

To investigate the feasibility of building an entire bridge using composite materials and then to monitor in-service performance.

NYSDOT
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D. Background

The United States civil engineering infrastructure is deteriorating at an alarming rate, and the cost of repair and replacement of these structures is staggering. More than 180,000 bridges (31.4 percent of the nation's bridges) are structurally deficient or functionally obsolete. The Federal Highway Administration estimates that their repair will cost more than $20 billion (1).

New York has 17,378 highway bridges (2) and 41 percent are structurally deficient. Of this total, 7,592 are maintained by the State DOT and the rest by local governments and other owners. Of the state-owned highway bridges, 29.5 percent are considered structurally deficient. According to a recent FHWA report, New York has twice the average state percentage of deficient bridges and leads all other states in this category (1). Although many of these deficient bridges are still safe for the traveling public, if preventive measures are not taken promptly they could pose safety hazards in the near future. Economical, durable alternatives thus must be pursued to rehabilitate or replace these deficient structures.

Most bridges (including those in New York) have been constructed using such conventional materials as steel, concrete, and wood. Rapid deterioration and associated costs in maintaining these structures warrant consideration of alternative construction materials. FRP composite materials, due to their strength and other material characteristics, offer great promise in solving many existing infrastructure problems in a cost-effective manner. Many of these deficient state-owned bridges maybe amenable to repair or replacement using advanced composite materials.

1. Desirable Properties versus Costs

Advanced composite materials originally developed for aerospace and defense applications have been of great interest to civil engineers and the construction industry because of their unique characteristics related to mechanical response and environmental durability. These materials are gaining importance in civil engineering structural applications due to their very high ratios of strength-to-weight. These applications, however, are still very limited due to only tentative understanding of failure mechanisms involved in laminated structures. It is well known that laminated and stiffened structures are highly sensitive to delamination failure. Occurrence of delamination leads to reduction of a structure's overall buckling strength. Often, delaminations are hidden and escape detection during routine inspection.

Despite widespread use of advanced composites in the aerospace and defense industries, applications in the civil engineering sector have been slow in developing, primarily because of costs. Key advantages of these composites -- such as outstanding strength/weight and stiffness/weight ratios, and a high degree of chemical inertness in most environments -- have been obscured by high material and manufacturing costs, as compared to conventional structural materials.

2. Recent Developments

Several developments have changed this picture over the last few years:

1. Reduced costs due to advances in manufacturing of polymer matrix composites in pultrusion, resin-transfer molding, and resin-infusion processes, as well as filament winding and automated manufacturing of large components.

2. Reduced demand for such composite fibers as carbon and aramids in the high-priced defense industries, as well as expansion of the highly competitive sporting-goods market and prospects for large-volume applications in the civil sector, leading to new, lower-cost manufacturing processes.

3. Design of cost-effective structural components (such as bridge decks) made of new materials for use in conventional structures to achieve technical efficiency at competitive cost.

4. New structural concepts and systems combining the superior mechanical characteristics of directional strength, in tension in the direction of the composite fibers, with the dominant characteristics of concrete in compression and steel in inelastic deformation capacity. One such concept is a new column or pylon system for bridges, using premanufactured carbon tubes as permanent formwork and reinforcement for cast-in-place columns or piers, thus completely eliminating the need for internal steel reinforcement and formwork removal.

3. Civil Engineering Applications

Advanced composites have shown particularly significant promise in rehabilitation of existing structural systems:

1. Strengthening of bridge superstructures with advanced composite overlays has been successfully demonstrated in Delaware, Florida, and Utah (3).

2. Seismic retrofitting of bridge columns with carbon-fiber wraps or preformed jackets has been demonstrated in California (4).

3. More then 30 pedestrian bridges have been constructed throughout the United States using pultruded composite structural shapes, including the longest composite I-girder bridge with a 18-m (60-ft) span in Kentucky's Daniel Boone National Forest (5).

4. The first US advanced composite vehicular bridge (the No Name Creek Bridge) was opened on December 4, 1996, in Russell, Kansas. The deck panels were shop-fabricated with composite honeycomb cells sandwiched between two face sheets. This bridge is 8-m (26-ft 3-in.) long and 8.3-m (27-ft) wide (6).

5. The Tech 21 Bridge on Smith Road in Ohio's Butler County, that state's first all-composite bridge, was opened on July 25, 1997. The bridge is 10-m (33-ft) long and 7.3-m (24-ft) wide. The deck is of sandwich construction consisting of pultruded tubes parallel with the traffic direction, between two face sheets. The deck is supported by three U-shaped structural beams (7).

6. Continuing research projects using composite reinforcing bars in concrete slabs are underway in New Hampshire, the District of Columbia, and Michigan (3).

7. Composite prestressing tendons and stay cables are being developed in Pennsylvania, Michigan, South Dakota, and California (3).

8. Demonstration bridge projects are being developed in Delaware, West Virginia, and California (3).

E. Work Plan

This project will consist of experimental work, analytical studies, and field testing progressing on approximately the schedule shown in Figure 1.

Fig. 1. Work-Time Schedule

Phase	Function	% of Effort	FFY 96 - 97	FFY 1997 - 1998				FFY 1998 - 1999				FFY 1999- 2000			
			IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
1	Study Proposal	2	x												
2	Literature Search	10	x	x	x										
3 4 5	Bridge Analysis, Material Selection & Design, and Material Testing	40			x	x	x	x							
6	Fabrication Procedure	10					x	x	x						
7	Bridge Construction	10							x	x	x				
8 9	Bridge Monitoring, Maintenance, and Repair	17									x	x	x	x	x
10	Reporting	5		x				x			x			x	x
11	Peer Review	2		x				x						x	
12	Data Management	4		x	x	x	x	x	x	x	x	x	x	x	x

Note : FFY: I - Oct-Dec; II -Jan- Mar; III - Apr - June; IV - July - Sep

1. Literature Search

The literature will be searched to identify previous work and provide background material for the analytical studies.

2. Bridge Analysis

This phase will develop specifications and guidelines through analysis, with the following main parameters:

1. Cost-effectiveness.
2. Light weight.
3. Corrosion resistance.
4. High load capacity to accommodate an MS 23 design truck.
5. Life expectancy exceeding 75 years.
6. Ease of construction.
7. Ease of transportation of prefabricated sections.

This project initially will be limited in scope to a two-lane simple-span bridge less than 30-m long, over a natural obstacle without vehicular or water traffic beneath the bridge to avoid possible traffic impacts. The bridge should be located on a secondary road with limited truck traffic. It is preferable to build the first bridge near Albany, so that it can be conveniently monitored by investigators from the NYSDOT Main Office and Rensselaer Polytechnic Institute. It will be analyzed to determine stiffness and stress characteristics of the composite-material structure as compared with AASHTO requirements for conventional structures.

3. Materials Selection and Design

Composite materials to match the stiffness and stress characteristics obtained in the analysis phase just described will be selected in this next phase. Composites have unique advantages over monolithic materials, such as high strength, low density, and long fatigue life. Material design, considering optimum material composition along with desirable structural characteristics, must include the following tasks:

1. Investigation of basic characteristics of composite materials and their constituents.

2. Structure optimization for given service conditions.

3. Development of analytical procedures to determine material properties and predict structural behavior.

4. Development of effective experimental methods for material characterization, stress analysis, and failure analysis.

5. Assessment of durability and service-life prediction.

6. Assessment of maintainability and repairability.

In choosing the types of composite materials for specific portions of the bridge, two items must be considered:

1. E-glass is the most common, least expensive glass fiber, highly desirable on a unit-cost basis, but it also can be sensitive to an alkaline solution (especially important in connection with concrete). The problem of creep and especially of creep rupture must be carefully addressed. Because of long-term creep, E-glass loses 70 percent or more of its tensile strength. E-glass loses almost half its tensile strength at elevated temperatures. Also, ultraviolet protection must be provided by a correctly chosen matrix -- polyester is much more sensitive in an aggressive environment, but less expensive than vinylester.

2. On the other hand, carbon fibers provide excellent stiffness and a good modulus at high temperatures, are highly corrosion-resistant, offer good resistance to creep and creep rupture, but are considerably more expensive than E-glass fiber.

4. Material Testing

Selected materials will be tested:

1. To determine basic properties of unidirectional lamina as input in structural design and analysis.

2. To investigate and verify analytical predictions of mechanical behavior.

3. For independent experimental study of material and structural behavior under specific geometries and loading conditions.

Under these general objectives, specific types and applications of testing include the following:

1. Characterization of constituent materials (i.e., fiber, matrix) to predict behavior of lamina and then of laminates in structures.

2. Determination of interlaminar properties and resistance to delamination growth in terms of the interlaminar fracture toughness.

3. Material behavior under special loading conditions -- i.e., fatigue, creep, impact, and high rate of loading.

4. Experimental stress and failure analysis of composite laminates and structures. Experimental methods for characterization and testing of composite materials are much more complex than for isotropic materials and require significant modifications (8, 9, 10, 11, 12).

5. The roadway wearing course, which must be specially addressed due to lack of experience in this application.

5. Fabrication Procedure

Using conventional materials, material fabrication and structure fabrication are two separate processes, but for composite materials, these are a single process. The fabrication process is one of the most important steps in use of composite materials. A variety of fabrication methods are available and suitable for several applications, including autoclave molding, filament winding, pultrusion, and resin-transfer molding. Structural components consisting of different materials, such honeycomb-sandwich structures, can be manufactured in one step, thus reducing the number of joints required. The best choice among available methods must be discussed in consultation with appropriate fabricators.

6. Bridge Construction

Based on the design guidelines developed earlier in this project, a fully composite bridge will be designed with assistance from other Divisions and constructed under NYSDOT supervision. Principal investigators (PIs) will assist the Department in developing PS&E's and during its construction. PIs will also develop specifications for monitoring and inspection.

7. Bridge Monitoring

The new test bridge will be instrumented with necessary sensors, at locations based on results of appropriate analytical studies. Data will be collected and analyzed as necessary.

8. Maintenance and Repair

Depending on materials chosen for the bridge, a maintenance and repair program will be discussed with representatives from each of the participating Divisions. Maintenance guidelines will be prepared.

9. Reporting

Results of this study will be summarized in an interim report and a final research report to the participating Divisions.

10. Peer Review

This study proposal and all reports will be peer-reviewed by participating Divisions and external peer-reviewers as defined in the Transportation Research and Development Bureau's Policies and Procedures Manual. External peer reviewers will be chosen by the principal investigators according to guidelines discussed in the Policies and Procedures Manual. Initial peer review are included in Appendix A of this study proposal.

11. Data Management

The project data, reports, and other documentation will be archived and maintained according to the "Data Management Guidelines" established in the Policies and Procedures Manual.

F. Benefits

A systems approach will enhance NYSDOT's knowledge of composite materials in new bridge construction. This will produce preliminary specifications and guidelines for the analysis, and will help develop comprehensive criteria for materials, design, fabrication, construction, repair, and maintenance. Finally, it will produce recommendations for methods in field investigation of long-term mechanical behavior and environmental durability of fully composite bridges.

G. Staff

This study will be performed under general supervision of Dr. Robert J. Perry, Director of Transportation Research and Development, and Dr. Sreenivas Alampalli, Engineering Research Specialist. The NYSDOT Structures Division and TR&DB have asked Rensselaer Polytechnic

Institute (RPI) to cooperate in this research. RPI has world-renowned experts and excellent facilities for composite research. The study will be conducted by Tadeusz C. Alberski, Civil Engineer II, with supporting staff assigned as needed under technical supervision of Professor George Dvorak of RPI. Qualifications of PIs are presented in Appendix B. A representative from each participating Division will review the program and assist TRDB with their input as required at various stages of the project (Appendix C).

NYSDOT staff monitoring this study will include James H. Bishop, Construction Division; Stephen L. Borg, Geotechnical Engineering Bureau; William H. Burdick, Design Division; Gerald R. Perregaux, Materials Bureau; Robert Sack, Transportation Maintenance Division; John J. Wheeler, Jr., Geotechnical Engineering Bureau; and Arthur P. Yannotti, Structures Design and Construction Division.

H. Technical Data, Proprietary Rights, Publicity

All technical data obtained during the course of this project, whether existing in the offices of RPI or in the offices of New York State, shall be made available to the other cooperating agencies without expense to such cooperating agencies.

All documents and data pertaining to the project at all times shall be the property of the State and the Federal Highway Administration to reproduce, publish, and otherwise use for any purpose. It is agreed that the RPI shall have the right under all circumstances to copy and use all such documents, data, and material.

If patentable discoveries or inventions should result from work described herein, all rights accruing from such discoveries or inventions shall be sole property of the State; the State of New York will have a nonexclusive, nontransferable license to make, use, and sell each subject invention throughout the world by and on behalf of the Government of the United States and state and domestic municipal governments, all in accordance with the provisions of 37 CFR Part 401 and 49 CFR Part 18.

RPI shall obtain written approval from the State before issuing, causing to be issued, or permitting to be issued any press release or advertisement, and before conducting or permitting to be conducted any interview or news conference in which this work is referred to or discussed. In any such press release, advertisement, or at any such interview or news conference, RPI shall identify, or cause to be identified the State as the sole or partial sponsor of the work. It is recognized that during the course of this work, RPI may from time to time desire to publish information regarding scientific or technical developments made or conceived in the course of this work. In order that public disclosure of such information will not adversely affect the interests of the State, RPI shall provide the State a copy of such information intended for publication prior to submission of the information for publication and allow the State a minimum of 60 days for review and comment.

I. References

1. The Status of the Nation's Highway Bridges: Highway Bridge Replacement and Rehabilitation Program, and National Bridge Inventory. Thirteenth Report to the United States Congress, Federal Highway Administration, U.S. Department of Transportation, May 1997.

2. "Distribution of Official Bridge Data 1997." Internal memorandum, Structures Design and Construction Division, New York State Department of Transportation, June 27, 1997.

3. F. Seible and V. Karbhari. "Advanced Composites Build on Success." Civil Engineering, August 1996 (Vol. 66, No. 8), pp. 44-47.

4. Evaluation for Plan for Composite Column Wrap Systems for Seismic Retrofit (:) Robo-Wrapper and Snap Tite. Final Plan, Highway Innovative Technology Evaluation Center, U.S. Department of Transportation, August 1997.

5. "The Clear Creek Bridge demonstration project: a photo essay." Composites Design & Application, March-April 1997, pp. 18-19.

6. "New bridge-building concept demonstrated." Composites Design & Application, Winter 1996, p. 9.

7. "Tech 21 -- Ohio's First Composite Bridge Dedicated Today." News release, Butler County (Ohio) Engineer's Office, dated July 25, 1997.

8. J.M. Whitney, I.M. Daniel, and B. Pipes. Experimental Mechanics of Fiber Reinforced Composite Materials. Monograph 4, Society for Experimental Mechanics (Bethel, CT), Englewood Cliffs, NJ: Prentice-Hall, 1985 (rev. ed.).

9. I.M. Daniel, "Methods of Testing Composite Materials." In Fracture Mechanics and Methods of Testing (G.C. Sih and A.M. Skudra, vol eds.), Handbook of Fibrous Composites (A. Kelly and Y.N. Rabonov, eds.), Amsterdam: North Holland Publishing Co., 1985, pp. 277-373.

10. Y.M. Tarnopol'skii and T. Kincis. Static Test Methods for Composites. (G. Lubin, trans. ed.), New York: Van Nostrand Reinhold Co. 1985.

11. I.M. Daniel. "Composite Materials." In Handbook on Experimental Mechanics (A.S. Kobayashi, ed.), New York: VCH Publishers, 1993, pp. 820-904.

12. ASTM Standards and Literature References for Composite Materials. American Society for Testing and Materials, 1990 (2nd ed.).

J. Budget Estimate

Table 1. Budget estimate by functions and skill levels

Function	Person-Weeks Required					
	ERS II	CE II	CE I	SET	Editor	Director
Study Proposal	1	3	0	0	1	0
Literature Search	1	10	0	0	0	0
Bridge Analysis &Material Selection and Design	4	32	12	0	0	0
Fabrication Procedure	2	10	3	0	0	0
Bridge Construction	5	10	5	0	0	0
Bridge Monitoring, Maintenance, and Repair	5	12	6	8	0	0
Reporting	2	10	2	2	1	1
Peer Review	0	2	0	0	0	0
Data Management	0	2	0	0	0	0
Estimated Cost	37,000	157,000	35,000	9,000	3,000	3,000
Total Personal Services $ 244,000						

Table 2. Budget estimate by project duration

Skill Level	Person-Weeks Required			
	1996-1997	1997-1998	1998-1999	1999-2000
Director	0	0	0	1
ERS II	1	7	8	4
CE II	12	26	26	26
CE I	6	8	8	6
SET	0	0	2	6
Editor	1	0	0	1
Estimated Cost	$32,000	$ 70,000	$ 74,000	$68,000
Total Personal Services: $ 244,000				

Table 3. Budget estimate by function.

Function	Cost
Personal Services	$ 244,000
Travel	$ 20,000
Supplies	$ 10,000
Equipment	$ 5,000
Other	$ 5,000
RPI Services	$ 25,000
Total	$ 309,000

Appendix A. Peer-Review Comments

Daniel R. Mertz, University of Delaware
Frieder Seible, University of California, San Diego

UNIVERSITY OF DELAWARE

COLLEGE OF ENGINEERING

DEPARTMENT OF
CIVIL & ENVIRONMENTAL
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Ph: 302/831-2442
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January 28, 1998

Dr. Robert J. Perry, Director
Transportation Research and Development Bureau
New York State Department of Transportation
Albany, NY 12232

RE: Study Proposal for Research Project 227-1
"Composite Materials in Highway Bridge Construction"

Dear Dr. Perry:

I have reviewed the subject proposal, and find it to be quite good. I find it refreshing that a Department of Transportation would initiate such a project. It is my experience that material or component suppliers are usually the initiators and bring little true bridge design and construction experience "to the table." I believe that it is most appropriate for bridge engineers to initiate such efforts.

I do however have a few concerns, which should be addressed (perhaps they have already been considered, but not enumerated in the proposal):

(1) Phases 3 through 7 are shown as being sequential in Figure 1, the Work-Time Schedule. Fabrication issues, as well as to some degree construction issues, must be considered during the analysis and testing. They should, in my opinion, be concurrent, as some iteration may have to occur.

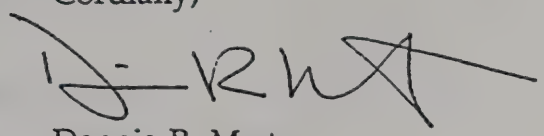
(2) The Budget, shown in Table 3, does not appear to include any material, fabrication or construction costs for the proposed bridge. I assume that these items will be covered in a sparate construction contract.

(3) During Phase 8, much could be learned regarding the bridge performance by embedding fiber optics in the composite components. This would be costly, and I don't see such cost in the budget.

(4) Finally, not everyone can fabricate and erect a composite bridge. The State should have some specific fabricators and suppliers in mind. Unfortunately, the poor availability of good fabricators, in my opinion, can drive the bridge design.

With regard to technical issues, the proposal is sound. The issues raised above not withstanding, I recommend the implementation of this work wholeheartedly.

Cordially,



Dennis R. Mertz
Associate Professor of Civil Engineering

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January 14, 1998

Dr. Robert J. Perry, Director
Transportation Research & Development Bureau
NYS Department of Transportation
Building 7A, Room 600
1220 Washington Avenue
Albany, NY 12232-0869

RE: Study Proposal for Research Project 227-1 on "Composite Materials in Highway Bridge Construction"

Dear Dr. Perry:

I have reviewed the above proposal which was sent to me on December 11, 1997. The proposal overall is very general in the cognizance of the important issues. These issues have been raised and addressed worldwide over the past decade. Unfortunately we are still facing significant "first-cost" problems with new advanced composite bridge construction which has limited worldwide applications to demonstration projects only. Enclosed for your information are two documents in which I have published my views on this matter.

The provided study proposal aims to address some of the key issues and I am in full support of such a project. We have a similar project ongoing here in California with Caltrans for the last five years. In order for the proposed project to be successful, very quickly, specifics need to be defined in order to focus the research effort. I will be glad to assist the State of New York Department of Transportation in this matter.

Sincerely yours,

Frieder Seible, Ph.D., P.E.
Professor and Chair
Division of Structural Engineering

/lb

Enc.

Appendix B. Principal Investigators

Sreenivas Alampalli
Tadeusz C. Alberski
George J. Dvorak

SREENIVAS ALAMPALLI
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Transportation R&D Bureau, NYSDOT
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EDUCATION

Ph.D. in Civil Engineering (1990), Rensselaer Polytechnic Institute, Troy, NY.

M.S. in Civil Engineering (1985), Indian Institute of Technology, Kharagpur, India.

B.S. in Civil Engineering (1983), Sri Venkateswara University, Tirupati, India.

EXPERIENCE

Transportation Research & Development Bureau, NYSDOT, Albany, NY.
- Head, Structures Research, August 1996 - Present
- Engineering Research Specialist I, August 1990 - August 1996

Union College, Schenectady, NY.
- Adjunct Professor, January 1995 - July 1995

Department of Irrigation, A.P. State, India.
- Assistant Executive Engineer, January 1986 - August 1986

AREAS OF INTEREST

Bridge Engineering, Nondestructive Testing, Earthquake Engineering, Data Acquisition, Instrumentation, Structural Dynamics, and Soil-Structure Interaction.

LICENSE

Registered Professional Engineer - New York State.

PROFESSIONAL ACTIVITIES

Transportation Research Board
- Member and Reviewer
- Committee A2K05 on Modeling Techniques in Geomechanics (1993-1995)
- Committee A2K01 on Soil and Rock Instrumentation (1997-Present)
- Committee A2C05 on Dynamics and Field Testing of Bridges (1998-Present)

American Society of Civil Engineers
- Member and Reviewer
- Structural Engineering Institute
  - Committee on Methods of Monitoring and Evaluating Structural Performance (1990-Present)
  - Committee on Structural Identification of Constructed Facilities (1994-Present)
  - Committee on Methods of Analysis (1997-Present)
  - Committee on Bridge Management, Inspection, and Rehabilitation (1997-Present)

American Society of Civil Engineers
Codes and Standards Activity Council
Committee on Independent Peer Review of Civil Engineering Projects (1992-Present)
Technical Council on Forensic Engineering
Committee on Technology Transfer and Implementation (1997- Present)

American Society for Nondestructive Testing
Member
Committee on Acoustics and Vibrations (1993-Present)
Committee on Handbook Development (1993-Present)

RECENT PUBLICATIONS

Elgamal, A-W., Alampalli, S., and Van-Laak, P. "Forced Vibration of Full-Scale Wall-Backfill System," Journal of Geotechnical Engineering Division, ASCE, Vol. 122, No. 10, pp. 849-858, 1996.

Alampalli, S., Fu, G., and Dillon, E.W. "Signal Versus Noise in Damage Detection by Experimental Modal Analysis," Journal of Structural Engineering Division, ASCE, Vol. 123, No. 2, pp. 237-245, 1997.

Alampalli, S., and Peddibotla, V. "Laboratory Investigations on Caisson-Deformations and Vertical Load Distributions," SOILS AND FOUNDATIONS, Journal of Japanese Geotechnical Society, Vol. 37, No. 2, pp. 61-69, June 1997.

Alampalli, S., and Fu, G. "Remote Bridge Monitoring Systems for Bridge Condition," Journal of Low Frequency Noise, Vibration, and Active Control, Vol. 16, No.1, pp. 43-56, 1997.

Fu, G., Pezze, F., and Alampalli, S. "Diagnostic Load Testing for Bridge Load Rating," Transportation Research Record 1594, National Research Council, Washington, D.C., pp. 125-133, 1997.

Alampalli, S., and Elgamal, A-W. "Dynamic response of Wall-Backfill Retaining System," Journal of Shock & Vibration, Vol. 4, No. 4, pp. 251-259, 1997.

Lall, J., Alampalli, S., and DiCocco, E.F. "Performance of Full-Depth Shear-Key in Adjacent Prestressed Box Beam Bridges," PCI Journal, Vol. 43, No. 2, March-April 1998, pp. 72-79.

Alampalli, S. "Response of Untethered-Span-Wire Signal Poles to Wind Loads," Journal of Wind Engineering and Industrial Aerodynamics. (to appear)

Alampalli, S., and Yannotti, A. "Long-Term performance of Integral Bridges and Jointless Decks." Transportation Research Record, National Research Council, Washington, D.C. (to appear)

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Registration:

State of Michigan, PE, License Number 38126.
State of New York, PE, License Number 070759.

Professional Experience:

New York State Department of Transportation, Structures Design & Construction Division, Albany, NY (June 17, 1993 -present). Senior Civil Engineer. Perform structural analysis for various highway and railroad bridges, and analysis of selected components of bridges and culverts, using advance computer's technology.
Representative Design Projects:
The 112th. Street Bridge over Mohawk River in Troy. NY, responsible for design of superstructure.
Carpenter Rd over Metr-Rairoad - First segmental concrete channel bridge, responsible for design of substructure.
Rt. 28 over Academy St., responsible for design of superstructure.
Long Island Expressway over Queensboro Boulevard Bridge, responsible for design of rehabilitation of whole structure.

University of Michigan, Department of Civil and Environmental Engineering, Ann Arbor, MI (1989-93). Design/Research Engineer responsible for the design, analysis and testing of bridges.
The major projects include:
"Development of LFRD Bridge design code for AASHTO", NCHRP Project 12-33. My responsibilities include the preparation of the reports and papers using computer graphics.
"Effect of the truck load on bridges", sponsored by Michigan DOT. My responsibilities include instrumentation of bridges, measurement of truck loads, assistance in processing of the data. Weight-in-motion (WIM) system developed by BWS is used.
"Calibration of OHBDC", sponsored by Ontario Ministry of Transportation. My responsibilities involve preparation of the reports and papers using computer graphics.
"Evaluation of Woodrow Wilson Bridge", sponsored by FHWA. My responsibilities include instrumentation and measurement of truck loads on Woodrow Wilson Bridge in Washington DC.

Val Krynski Quality Construction Co. Chicago, Illinois (1988-89).
Site Supervisor - supervision of the residential housing development including design and construction.

Road and Bridge Construction Export Enterprise, Warsaw, Poland (1980-88).
Senior Structural Engineer responsible for complete bridge structural engineering design. Implemented design quality control throùghout projects and construction inspections. Designed several types of structures including reinforced and prestressed concrete bridges, culverts and retaining walls. Prepared bids for bridge construction. Manager of Bridge Department responsible for realization of bridge projects provided by Dromex at international market. Manager of Bridge Section responsible for construction of bridge part of section 7, Expressway No.1 in Iraq.

Railway and Bridge Construction Enterprise, Warsaw, Poland (1973-80).
Manager of Bridge Department responsible for construction and rehabilitation of railway bridges, control and design of structures. Senior Project Engineer responsible for complete structural design. Prepared proposals and project budgets. Developed and managed several bridge projects. Project Engineer responsible for construction, field investigations and coordination.

Representative Construction Projects:

Expressway No. 1 in Iraq (1982-86): Project included 32 reinforced concrete and prestressed concrete bridges, over 600 culverts, over 150 large diameter (4 & 5 ft) piles; total length of bridges over 9200 ft, about 180,000 cu yd of concrete.

Railway and highway bridges in Poland (1973-80).
Over 30 bridge **rehabilitation** projects includes: Legnicka Project Railway Bridge - Downtown Wroclaw - 11 track railway bridge, two steel box continuous spans @ 75 ft, over a 4 lane highway - without traffic hindrance; Malbork Project Railway Bridge - two railway bridge over Vistula River, 4 @ 180 ft orthotropic steel box continuous spans, rehabilitation of supports - deep foundations - large diameter (4 ft) piles , w/o interrupting traffic;
Kliniczna Highway Interchange Project - Downtown Gdansk - a highway bridge 27 spans @ 110 ft reinforced voided slabs, foundation under ground water level - temporary depression; pedestrian bridge over 7 lane railway; pedestrian tunnel under 4 lane railway (w/o interrupting traffic).
Several steel and concrete bridges for **new railway and highway projects**: Hrubieszow-Katowice railway lane (250 miles); Warszawa-Gdansk highway; Warszawa-Katowice highway.

Education: M.S and B.S in Civil Engineering, major in Bridge Structures, Warsaw Technical University, Poland ,1973.

Continuing Education:

Composite Materials, Finite Element Method I & II, Mechanic of Solids, Rheology, Structural Dynamics, Rensselaer Polytechnic Institute, Troy, New York, 1995-1997.

Specialty Course on Deep Foundation, Benoto Paris, France (1985).

Specialty Course on Expansion Joints, M.A.N. - GHH Stuttgart, Germany (1985).

Specialty Course on Bridge Bearings, Gumba, Gmbh Munchen, Germany (1984).

Specialty Course on Prestressing System, Freyssinet International, Paris, France (1983).

August 1997

GEORGE J. DVORAK
William Howard Hart Professor of Mechanics
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Rensselaer Polytechnic Institute
Troy, New York 12180-3590
(518) 276-6940; fax (518) 276-8784
email: dvorak@rpi.edu

Education:
C.E. Czech Technical University, Prague, 1956
C.Sc. Czechoslovak Academy of Sciences, Prague, 1964
Ph.D. Brown University, 1968

Citizenship: United States

Academic Appointments:

Brown University, 1964-1965
Research Associate, Division of Engineering

Duke University, 1967-1979
Professor of Civil Engineering, 1974-1979
Professor of Biomedical Engineering, 1977-1979
Director of Graduate Studies in Civil Engineering, 1972-1979

Cambridge University, Engineering Department, Cambridge, England
Senior Fellow, 1975-1976

University of Utah, 1979-1984
Professor and Chairman, Department of Civil Engineering, 1979-1984
Professor of Materials Science and Engineering, 1980-1984
Director, Center for Composite Materials, 1982-1984

Rensselaer Polytechnic Institute, 1984-present
Professor of Civil Engineering, 1984-present
Chairman of Civil Engineering, 1984-1995
Professor of Mechanical Engineering, Aeronautical Engineering and Mechanics, 1986-present
William Howard Hart Professor of Mechanics, 1995-present

Politecnico di Milano, Milan, Italy
Visiting Professor, Department of Structural Engineering, 1991

Technical University of Denmark, Lyngby, Denmark
Visiting Fulbright Professor, Department of Solid Mechanics, Spring 1995

Honors:

National Academy of Engineering, 1995
Doctor Honoris Causa, Czech Technical University, Prague, 1997
Nadai Medal, for pioneering research in the mechanics of modern materials, ASME, 1992
Medal of Merit for Contributions to Mechanics, Czechoslovak Academy of Science, Prague, 1992
Prager Medal, for outstanding contributions to the mechanics of solids, SES, 1994
Citation for Accomplishment of Special Merit, U.S. Army Research Office, 1977, 1979
Visiting Fellowship, Clare Hall, Cambridge, England, elected 1975
Senior Visiting Fellowship, British Science Research Council,1975
Fulbright Fellowship, Technical University of Denmark, 1995
Fellow, ASCE, ASME, American Academy of Mechanics, Society of Engineering Science
Lecturer, Midwestern Mechanics Seminar Series, 1986
Lecturer, Southwest Mechanics Seminar Series, 1992
Member, Scientific Advisory Board of the Academy of Science of the Czech Republic, 1993-1997
Member, U.S. Natl. Comm. on Theoretical and Applied Mechanics, 1994-present

Scientific and Professional Societies:

American Society for Engineering Education (1990-present)
American Society of Civil Engineers (1967-present)
- Engineering Mechanics Division
  - Committee on Properties of Materials (1972-80), Chairman (1978-80)
  - Editorial Board, ASCE J. of the Engn. Mech. Div. (1976-78)
  - Executive Committee (1982-86), Chairman (1984-85)
  - Advisory Board (1986-90), Chairman (1988-89)

American Society of Mechanical Engineers (1968-present)
- Applied Mechanics Division
  - Committee on Composite Materials, Chairman (1981-89)
  - General Committee (1982-89), Program Committee (1981-89)

American Academy of Mechanics (1985-present)
American Ceramic Society (1993-present)
Society of Engineering Science (1970-present)
- Board of Directors (1974-77, 1985-92), President (1988-89)

Other Activities:

Editorial Board, ASCE Journal of the Engineering Mechanics Division, 1976-78
Associate Editor, Applied Mechanics Reviews, ASME 1985-1995
Associate Editor, International Journal of Plasticity, Pergamon Press, 1984-present.
Associate Editor, ASME Journal of Applied Mechanics, 1989-1995.
Editorial Board, Mechanics of Composite Materials and Structures, 1993-present.
Chair and member of many scientific committees, for national and international conferences and symposia, including the 1998 U.S. National Congress on Applied Mechanics.
Director, DARPA/ONR URI Program on High Temperature Advanced Structural Composites, 1990-92
Director, ARPA/ONR URI Program Mechanism-Based Design of High-Temperature Composite Structures 1992-1997
Principal investigator on numerous projects on many aspects of mechanics and mechanical behavior of composite materials, sponsored by AFOSR, ARO, ARPA, NSF and ONR, 1971-present.

Appendix C. Project Initiation Correspondence

MEMORANDUM
DEPARTMENT OF TRANSPORTATION

TO: R. J. Perry, Transportation R&D Bureau, 7A-600 MC 0869

FROM: J. M. O'Connell, Structures Division, 5-600 MC 0600

SUBJECT: **COMPOSITE MATERIALS IN HIGHWAY BRIDGE CONSTRUCTION**

DATE: May 14, 1997

This confirms our earlier discussions on designing and building a fully composite bridge superstructure and then monitoring its in-service performance. Rapid deterioration and associated costs in maintaining highway structures built with conventional materials warrant the consideration of alternative construction materials. Fibre-reinforced-plastic (FRP) composite materials, due to their strength and material characteristics, seem to offer great promise in solving many existing roadway infrastructure problems. Although extensive research is underway nationwide in using FRP for bridge retrofitting applications, there has been limited progress in using FRP for new construction. Research in this area seems to have followed a single component approach (i.e. focussed on such individual components as decks, girders, piles, etc.). I believe a broader approach would be more beneficial in advancing FRP use in new bridge construction.

That broader approach will enhance the Department's knowledge of use of composite materials in new bridge construction and will help develop comprehensive criteria for materials, design, fabrication, construction, repair, and maintenance of fully composite bridge superstructures. I would like your Bureau to initiate a project to investigate the feasibility of building an entire superstructure using composite materials.

As you are aware, the Rensselaer Polytechnic Institute has a Center for Composite Materials and Structures. Their center has world-renowned experts and excellent facilities for composites research. Their input and advice in this project would be invaluable. One cost-effective way to take advantage of their services will be to ask one of our employees to work with

the center as a research fellow. This will provide access to RPI's experts and facilities. I can lend Tadeusz C. Alberski of my staff to work with your Bureau half-time until this project is completed. He will work as your employee during that period, and is willing to work with RPI to research this problem in cooperation with the RPI Composites Center.

If you have questions or desire further information, please contact me.

JMOC:slm

cc: K. W. Shiatte, Ofc. of Engineering, MC 0504
P. Mack, Technical Services Division, MC 0862
S. Alampalli, Transp. R&D Bureau, MC 0869
T. Alberski, Structures Division, MC 0600
G. A. Christian, Structures Division, MC 0600

MEMORANDUM
DEPARTMENT OF TRANSPORTATION

TO: P. T. Wells, Construction Division, 4-101, MC 0410
P. J. Clark, Facilities Design Division, 5-405, MC 0748
E. G. Fahrenkopf, Highway Maintenance Division, 5-217, MC 0337
W. Moody, Geotechnical Engineering Bureau, 7-102, MC 0863
W. J. Brule, Materials Bureau, 7A-210, MC 0861

FROM: R. J. Perry, Transportation R&D Bureau, 7A-600, MC 0869

SUBJECT: **PROJECT R 227-01-881: COMPOSITE MATERIALS IN HIGHWAY BRIDGE CONSTRUCTION**

DATE: May 21, 1997

Please find enclosed a copy of the project initiation statement of a research project entitled "Composite Materials in Highway Bridge Construction." This project was initiated at the request of the Structures Design and Construction Division. Since your program area is likely to be involved with the implementation of the project results, we would like you to designate a representative of your program to help us carry out this research. We would appreciate it if your representative could contact Dr. Sreenivas Alampalli at 457-5826 by May 29, 1997.

RJP:SA:nat
attachment

c (with enclosure):
J. M. O'Connell, Structures Division, 5-600, MC 0600
T. Alberski, Structures Division, 5-600, MC 0600
A. H. Malik, Structures Division, 5-600, MC 0600
L. Johanson, Structures Division, 5-600, MC 0600

New York State Department of Transportation
Transportation Research and Development Bureau

PIN: R-227-01-881

INITIATION OF NEW PROJECT

PROJECT: COMPOSITE MATERIALS IN HIGHWAY BRIDGE CONSTRUCTION

MANAGER: Sreenivas Alampalli

PROBLEM: Rapid deterioration and associated costs in maintaining highway structures built with conventional materials, warrant the use of alternative construction materials. Fibre-reinforced-plastic (FRP) composite materials, due to their strength and material characteristics, seem to offer great promise in solving many existing roadway infrastructure problems. Although, extensive research is underway nationwide in using FRP for bridge-retrofitting applications, there has been limited progress in using FRP for new construction. Research in this area seems to have followed a component approach (i.e. focussed on such individual components as decks, girders, piles, etc). A systems approach will be much more beneficial in advancing FRP use in new bridge construction.

OBJECTIVE:

1) To investigate the feasibility of building an entire bridge, from foundation to appurtenance, using composite materials.
2) Building a fully composite bridge and then monitoring its in-service performance.

BENEFITS: Will enhance the Department's knowledge of use of composite materials in new bridge construction and will help develop comprehensive criteria for materials, design, fabrication, construction, repair, and maintenance of fully composite bridges.

STATUS: New

6-MONTH PLAN: Conduct comprehensive search of existing literature, on-going projects, and planned research. Establish contact and cooperation with Rensselaer Polytechnic Institute's Center for Composite Materials and Structure, to take advantage of its experts and excellent facilities for composites research. Prepare a synthesis and a study proposal. Establish a project peer-review team and data management scheme.

TOTAL COST: TBD **EQUIPMENT:** TBD

EST'D 1997 COST: $25,000 **EQUIPMENT:** None

CLIENT: Structures Design and Construction Division, Geotechnical Engineering Bureau, Materials Bureau, Construction Division, Design Division, Maintenance Division.

PROJECT COMPLETION DATE: TBD

MEMORANDUM
DEPARTMENT OF TRANSPORTATION

TO: R. J. Perry Transportation R&D Bureau, 7A-600, M.C. 0869

FROM: Wesley P. Moody, Director, Geotechnical Engineering Bureau, 7-102, M.C. 0863
By: Phillip A. Walton Phillip A. Walton

SUBJECT: PROJECT R227-01-881: COMPOSITE MATERIALS IN HIGHWAY BRIDGE CONSTRUCTION

DATE: June 3, 1997

As discussed by telephone with Dr. Sreenivas Alampalli, there are two people from this Bureau with particular interest in use of composite materials in bridge construction. Steve Borg, (7-4770) has been associated with the use of piles made of recycled reinforced plastic in construction. Both Steve and the second nominee, Jack Wheeler, have a general interest in using composite materials in bridges. They will share the responsibility of representing this Bureau in the research effort.

Please notify us of your schedule for meetings.

PAW:DMH

c: J. O'Connell, Structures Division, 5-600, M.C. 0600
Paul J. Mack, Director, Technical Services Division, 7A-210, M.C. 0862

MEMORANDUM
DEPARTMENT OF TRANSPORTATION

TO: R. J. Perry, Transportation R&D Bureau, 7A-600, MC 0869

FROM: W. J. Brule, Materials Bureau, 7A-210 M.C. 0861
By G. R. Perregaux, General Engineering, 7A-220B

SUBJECT: **PROJECT R 227-01-881: COMPOSITE MATERIALS IN HIGHWAY BRIDGE CONSTRUCTION**

DATE: May 28, 1997

Composite materials for highway bridge construction are new to the Bureau in that we have few standard procedures in place for testing their physical properties or for providing quality assurance of the manufacturing or fabrication processes.

The General Engineering Section of the Materials Bureau is assigned this responsibility and will assist in the implementation of your project results. Jerry Perregaux (or his designee) is our representative and may be contacted at 457-4285.

WJB:GRP:DMD

File: 17.1-1

From: Bill Burdick
To: DOTDOM4.TRDB.SALAMPALLI
Date: 5/28/97 10:44am
Subject: Project R 227-01-881: Composite Materials in Highway Bridge Construction

This documents our telephone conversation of May 28 regarding the Design Division's role in the subject study. The Division will serve in an overview role rather than an active research role. It is estimated that this will require approximately one day per month. Study materials are to be forwarded to me at the Design Division Office for disposition.

CC: PCLARK

From: James O'Connell
To: DOTDOM4.TRDB.SALAMPALLI
Date: 6/23/97 10:51am
Subject: Research Project - Composites in Highway Bridge Construction -Reply

The Str Div contact person for the subject research project will be Art Yannotti. Art can be reached at 51148.

CC: AYANNOTTI

01575
LRI